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Profiles

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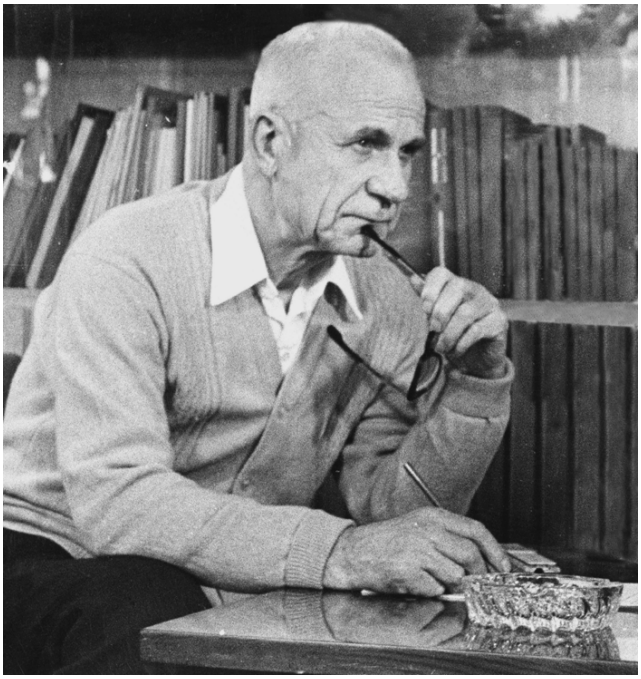
The Pioneer of National Jet Engineering

On the Centenary of the Birth of Academician A.M. Lyul'ka

A.M. Lyul'ka was an outstanding scientist and engineer; he was a theoretician, a designer, and the organizer of a large team effort, but, above all, he was a pioneer and an innovator. His biography is part of the history of air-breathing jet engines and novel aviation.

Academician S.A. Khristianovich



Arkhip Mikhailovich Lyul'ka.

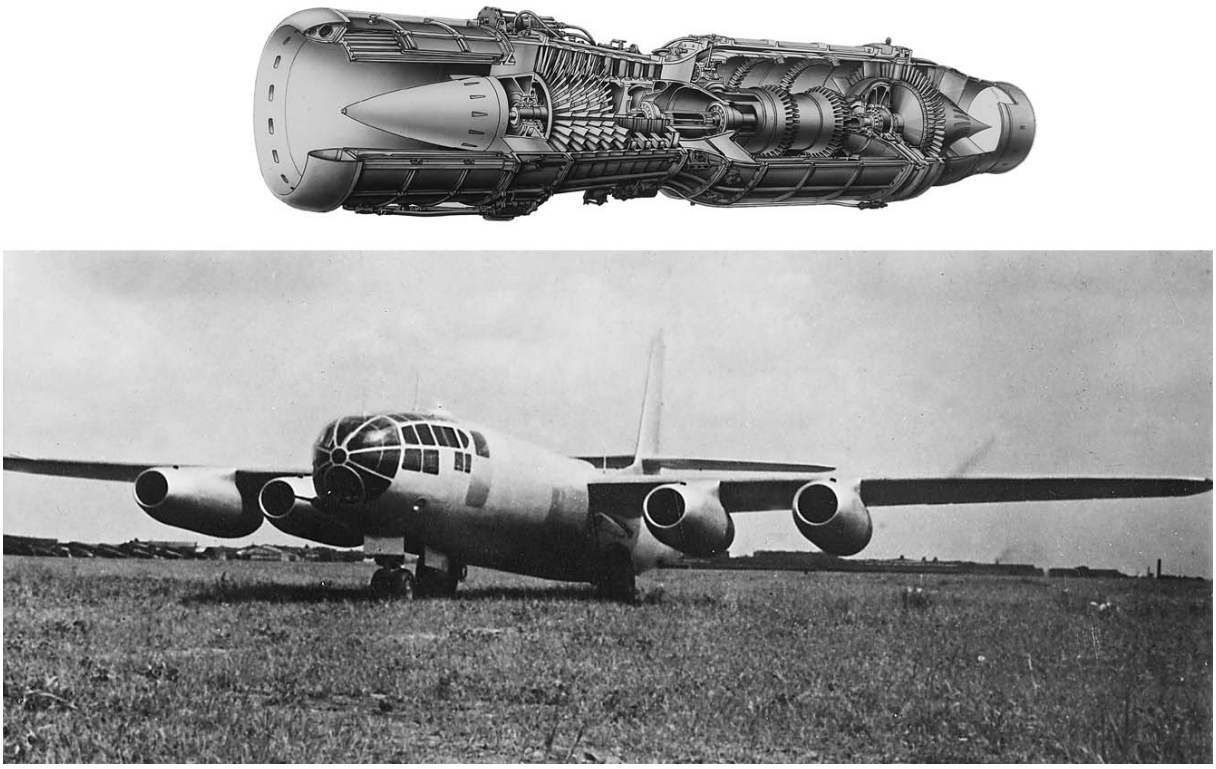
Arkhip Mikhailovich Lyul'ka was born March 23, 1908, in the village of Savarka, Kiev province, into a large peasant family with eight children. When he was seven, his mother died, and then, in 1925, his father came to a tragic end. In those hard years, his school, in which wonderful teachers worked, played a significant role in the life of young Lyul'ka. One of them was Mikhail Filippovich Kravchuk, the principal and a teacher of mathematics. (Later, he was engaged in research and teaching at the Kiev Polytechnic Institute and was voted into the Academy of Sciences of the Ukrainian Soviet Socialist Republic.) Kravchuk imparted a love of exact sciences in his student and remained his mentor for many years. Lyul'ka followed his advice and went to a vocational school in Belaya Tserkov'. Upon finishing it, he successfully passed the entrance exams for the Kiev Polytechnic Institute. After graduating from the institute in 1931 with a degree in turbine construction, Lyul'ka worked for several years in Khar'kov: first, at the Research Institute of Industrial Energy, then, at the Khar'kov Turbine Works, and in 1933 he began working at the Aircraft Engine Department of the Khar'kov Aviation Institute.

At that time, aircraft with piston engines and propellers dominated overwhelmingly in aviation. Aircraft were constructed in the thousands. Their qualitative performances—velocity, altitude, flight range, and lifting power—were growing rapidly. However, aviation specialists found it increasingly difficult to meet the requirements of improving the engineering specifications of aircraft piston engines. Power augmentation led to a considerable increase in engine weight and size, which was unacceptable for aircraft design.

The Kirov Factory in Leningrad and the Khar'kov Aviation Institute started to design a steam-power plant for aircraft. Replacing the piston engine by a steam turbine was technically justified. The steam turbine was well studied, had had many years of stationary operation experience, and, more importantly, allowed one to obtain power several times higher than that of the piston engine.

Lyul'ka, who had gained some experience in designing steam turbines, was engaged in the aircraft steam plant program. Project manager Prof. V.T. Tsvetkov commissioned him with the design of a condenser intended for condensing spent steam. This unit of the steam-power plant was fatal for the whole project. The size of the condenser turned out to be so large that it was impracticable to install it on aircraft.

The inability to apply a steam turbine to aviation made the designers search for new areas in the develop-



The Russian TR-1 turbojet engine, designed by Lyul'ka, and the Il-22 aircraft, where this engine was installed.

ment of power plants for high-speed aircraft. It was 1937. Professor B.S. Stechkin had already published his papers on the theory of the air-breathing engine and its use as a power plant for propellerless planes. Earlier, in 1935, V.V. Uvarov had theoretically substantiated the possibility of using a gas turbine in aviation. Lyul'ka recollected that the book by Professor M. Roi from the French National Higher School of Aeronautics *Rocket Apparatuses: Useful Action and Application Conditions*, translated into Russian in 1936, had greatly influenced his world outlook.

A small group of young engineers from the Khar'kov Aviation Institute headed by Lyul'ka started to design a turbojet engine with a centrifugal pump for the KhAI-2 fighter. Estimations showed that the aircraft would be able to attain a top speed of 900 km/h, which almost doubled the maximum attainable flight speed at that time. The project effort was outside the scope of work of the institute, and, in the management's opinion, diverted the staff from teaching. At that time, Lyul'ka lectured on thermodynamics and conducted practical classes in heat transfer. Therefore, all turbojet engine calculations and design developments were performed after hours, mostly at night.

Design documents were compiled in a thick volume entitled "RTD-1 Design" (RTD is the Russian abbreviation for Turbojet Engine). When reviewing the design, the academic council of the Khar'kov Aviation Institute did not rank it high, but Prof. G.F. Proskura, head of the Aerodynamics Department, recommended sending Lyul'ka and the design documents to Moscow. At an expert commission meeting, which was held at the Aviation Department of the People's Commissariat (Narkomat) of the Defense Industry, the design was highly commended. Of great importance was the appreciation of Lyul'ka's design by Professor V.V. Uvarov, of the Moscow Higher Technical School, who was a major expert in gas turbines. Later, Uvarov wrote:

> It took my deputy M.I. Vostrikov and me a week and a half to review Lyul'ka's "treatise," and, as the saying goes, truth was born of arguments. I was able to digress from my biased opinion and give a true value to the submitted design. The report I wrote must have been the most favorable in all my life.

Then, the Narkomat of the Defense Industry made the decision to support Lyul'ka's design, allocate funds, and provide appropriate facilities for practical work at the Kirov Factory in Leningrad. Lyul'ka was appointed technical project manager at the Kirov Factory's SKB-1 Special Design Bureau. In 1939, he and his group moved from Khar'kov to Leningrad and started to design a 400- to 500-kgf RD-1 turbojet engine. In contrast to the Khar'kov centrifugal compressor engine, RD-1 was designed with an axial six-stage compressor. It was expected that the new motor would be installed on a high-speed fighter designed by A.A. Arkhangel'skii.

Academician M.V. Keldysh, Academician V.A. Kotel'nikov, and Corresponding Member of the USSR Academy of Sciences A.M. Lyul'ka. 1961.

By 1940, the engine design was complete and the work order placed with the Kirov Factory. When individual units were being tested, the work had to be stopped, due to the beginning of the Great Patriotic War. All drawings, calculations, and fabricated engine components were carefully packed and safely hidden at the Kirov Factory.

Lyul'ka's group was evacuated to Chelyabinsk, where, at the Chelyabinsk Tractor Factory, they were commissioned to work on tank design, supervised by Chief Designer Zh.Ya. Kotin, and diesel aircraft engines, led by A.D. Charomskii. Only in late February 1942 was the question of resuming work on RD-1 brought before the Motor Department of the Red Army Air Force Research Institute, and Lyul'ka's team of 15 people moved from Chelyabinsk to the town of Bilimbai, Sverdlovsk oblast, where there was the Special Design Bureau of Factory 293, which had been evacuated there from Moscow in October 1941. The director and chief designer of the factory was V.F. Bolkhovitinov who was designing a BI-1 aircraft with a liquid-propellant jet engine. He did what he could to help Lyul'ka and provided conditions for resuming the RD-1 effort. In late 1942, Lyul'ka was sent to besieged Leningrad to fetch the RD-1 technical documentation and units from the Kirov Factory. Under unceasing fire, trucks took the precious load from the city across the ice of Lake Ladoga and transported it to the destination.

The continuation of work on the RD-1 design was significantly influenced by M.I. Gudkov, who was chief aircraft designer and, simultaneously, chief engineer of a central administrative board at the Narkomat of the Aviation Industry. He decided to equip his LaGG-3 plane with an RD-1 engine instead of the initially contemplated M105 piston engine with a jet-booster. Gudkov and Lyul'ka designed the layout of the LaGG-3 fighter equipped with the RD-1 engine and forwarded the project to the Central Institute of Aerohydrodynamics (TsAGI). The institute confirmed the accuracy of calculations and the feasibility of the parameters claimed: an engine thrust of 530 kgf and a flight speed of 900 km/h.

Gudkov asked I.V. Stalin to give approval for designing a jet fighter. In May 1943, this issue was discussed by the Central Party Committee at a meeting of a special commission chaired by G.M. Malenkov. The commission included Vice People's Commissar of Aviation and Chief Designer A.S. Yakovlev, Chief Designers V.Ya. Klimov and A.A. Mikulin, TsAGI's Chief S.N. Shishkin, and other people. The commission resolved that it would be premature to build a jet fighter, but admitted the design of such aircraft promising, and recommended to continue work on the turbojet engine.

Upon returning to Moscow from the evacuation in early October 1943, Lyul'ka and his group transferred to the Central Aviation Engineering Institute, where he was appointed head of the Jet Engine Research and Design Laboratory. At that time, it was known that aircraft with the jet engines Heinkel and Messerschmitt had appeared in Germany.

In 1944, the State Defense Committee issued decrees On Designing Jet Aircraft Engines and On Designing Aircraft with Jet Engines. Meanwhile, Lyul'ka's group developed a design for the M-18 (modernized) turbojet engine, which was later designated as S-18 (bench-type). The design was based on the RD-1 calculations and drawings. The C-18 parameters were about 2.5 times greater, the six-stage compressor was replaced by an eight-stage one, and the thrust grew from 530 to 1200 kgf. A meeting at the Ministry of the Aviation Industry approved the design and selected factories to fulfill the order.

In April 1944, Lyul'ka was transferred to Research Institute 1 (NII-1), where he was appointed head of

Professor V.V. Uvarov, Designer General Academician A.I. Mikoyan, Academician Lyul'ka, director of Factory 165 A.A. Zavitaev, and Academician S.K. Tumanskii. 1968.

Turbojet Engine Department 21. His group of designers came to work at NII-1 too. Already in August 1944, the first set of S-18 units and aggregates was manufactured; then they were assembled at Factory 165; and, at the beginning of September 1944, the engine was installed on the bench at NII-1. Finalization work continued until the end of November 1945 and ended with a successful 20-hour service test. The test validated the reference engine performance.

For successful testing of the pioneer national S-18 bench engine, Lyul'ka, a group of employees from his department, and the NII-1 management were awarded government decorations. Lyul'ka received his first order, the Red Banner of Labor.

On March 30, 1946, Minister of Aviation M.V. Khrunichev ordered the establishment of the experimental design bureau OKB-165 at Factory 165. Its purpose was to develop and design domestic turbojet engines, and Lyul'ka was appointed its head. Based on S-18, the OKB designed a TR-1 flight version of the engine. Moscow Motor Factory 45 (at present Salyut) was, along with Factory 165, to manufacture, fine-tune, and test its main components. Other aviation factories, design offices, and institutes were also involved in the creation of the TR-1 engine. On February 27, 1947, the first national turbojet engine passed a 20-hour service state test and showed a 1350-kgf thrust. Lyul'ka received a government telegram of congratulations from Stalin. Lyul'ka was decorated with the Order of Lenin, and then he received the State Prize. A large group of his teammates were awarded orders and medals.

The TR-1 engine was a remarkable event in the history of national propulsion engineering, and Lyul'ka was the pioneer in the Russian turbojet area. In addition, the year 1947 witnessed early flights of experimental fighters Su-11, I-211, and the Il-22 bomber with the TR-1 engine. The aircraft were piloted by Heroes of the Soviet Union G.M. Shiyanov and V.K. Kokkinaki.

The construction of the Su-11 plane with the TR-1 turbojet engine put together two outstanding aircraft designers of the 20th century—Pavel Osipovich Sukhoi and Lyul'ka—and laid the foundation for their fruitful long-term cooperation. Their design teams created aircraft of world renown, such as Su-7B, Su-9, Su-11, Su-17M, Su-24, and Su-27 and a host of their modifications. In the late 1940s, Lyul'ka supervised turbojet engines TR-1A, TR-2, and TR-3, which passed bench tests but were not installed on planes.

At that time Lyul'ka was on friendly terms with Academician Khristianovich, an expert in hydromechanics and gas dynamics. At Lyul'ka's request, Khristianovich gave a lecture course in supersonic gas flows at the OKB. He presented the OKB staff with the newly finished handwritten Table of Basic Gas-Dynamic Functions, which facilitated the designers' calculations of gas–air flow ducts during engine design.

In 1950, Lyul'ka's OKB designed a 5030-kgf engine. By government decision, engines created at Lyul'ka's OKB began to be designated by his initials AL—Arkhip Lyul'ka. The new engine was AL-5. Its flight test was carried out by test pilot Kokkinaki on board the Il-46 aircraft designed by S.V. Il'yushin. The engine was recognized as one of the best in the world, and Lyul'ka and a number of leading OKB experts were awarded the State Prize of the First Degree.

In 1952, the OKB started to design the AL-7 engine and, then, its modifications AL-7F, AL-7F1, and AL-7F2. These motors made the OKB world-known and generally recognized. The AL-7F engines were mass-produced by several factories. A few thousand aircraft Su-7B, Su-9, and Su-11, as well as the Tu-128 experimental aircraft and the Be-10 flying boat,

Academicians Lyul'ka, A.Yu. Ishlinskii, N.A. Pilyugin, and A.A. Logunov. 1976.

designed by G.M. Beriev, were equipped with AL-7F modifications. Beriev's plane set 12 world records. In 1957, Lyul'ka was awarded the title of the Hero of Socialist Labor for the creation of the AL-7F engine. He was appointed General Aeronautical Designer. In 1958, Lyul'ka was awarded the scientific degree of a doctor of engineering science, and in 1960 he was elected a corresponding member of the USSR Academy of Sciences at the Branch of Engineering Sciences.

In the years 1965–1972, Lyul'ka's OKB designed the third-generation turbojet engine AL-21F. The AL-21F3 engines, installed on frontline aircraft Su-24, Su-17M, and MiG-23B, operate successfully in many countries of the world to this day.

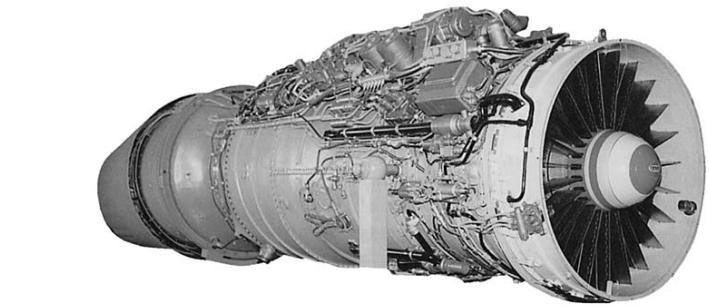
In 1968, the USSR Academy of Sciences elected Lyul'ka a full member at the Branch of Physicotechnical Energy Problems. For many years, Lyul'ka headed the Academy's Commission for Gas Turbines, which dealt with problem issues related to the operation of various power plants in Russia. Lyul'ka's great authority, profound professional knowledge, and immense practical experience contributed greatly to the progress of national gas energy engineering.

In addition to turbojet aircraft engines, Lyul'ka's OKB developed power units for other industries and purposes. In 1955, Lyul'ka's OKB was assigned to design a "nuclear" engine for a supersonic long-range bomber designed at an OKB headed by V.M. Myasishchev. The new type of engine, which utilized nuclear power for heating, was indexed as MT-35 (MT is the Russian abbreviation for model heat exchanger). The work was conducted jointly with the Kurchatov Institute of Nuclear Energy. This project did not go as far as practical implementation.

In the years 1959–1975, Lyul'ka directed the design of a liquid-fuel rocket engine D-57 and its modification with a retractable nozzle D-57M on cryogenic components—liquid oxygen and liquid hydrogen. The D-57 engine with a 40 ton-force thrust was intended for the N-1 lunar rocket complex. The engine passed a full set of requisite tests and manifested all design parameters, but the effort was stopped because of failures in launching the N-1 booster.

In the early 1970s, Lyul'ka started to work on his invention, for which he had received an inventor's certificate back in 1941—a mixed flow turbofan engine configuration. Today, this configuration is used to manufacture the absolute majority of turbojet engines worldwide.

In 1976, the Lyul'ka OKB began designing the fourth-generation engine AL-31F for the Su-27 frontline fighter. This engine became the summit of Lyul'ka's creative endeavors. The OKB team extensively applied the experience of national propulsion engineers: S.P. Izotov, P.A. Solov'ev, N.D. Kuznetsov, and others. For example, the high-pressure compressor of the AL-31F engine was derived from that of the RD-33 engine designed by Izotov. The designers had to face a series of grave technical difficulties, given the high heat-release rate and loading of the units of the low- and high-pressure compressors, the high-pressure turbine, and the combustion chamber. The biggest problem in the phase of development was the imperfection of the rotating high-pressure turbine blade. The problem was successfully overcome by using a cyclone vortex blade configuration. The AL-31F high efficiency and performance were accomplished thanks to the introduction of an air-to-air heat exchanger in the cooling system of the first- and second-stage nozzle dia-



The AL-31F turbojet engine, designed by Lyul'ka, and the Su-27 aircraft, in which this engine is installed.

phragms and the rotating turbine blades of the first stage. The air-to-air heat exchanger was installed in the secondary flow of the engine and cooled the bleed air after the ninth stage of the high-pressure compressor to 140–220°C.

The year 1981 saw the start of designing, under the direction of Lyul'ka, of special small-size engines for the hydraulic pump drive of the Energiya general-purpose space system with the Buran shuttle—the RTVD-14 turboshaft rocket engine for Buran and the TP-22 engine for Energiya. On November 15, 1988, the Energiya–Buran system accomplished its first and, as it turned out, last spaceflight.

For the successful design of new specimens of aeronautical engineering, Lyul'ka was awarded the Order of Lenin (1966), the Order of the October Revolution (1971), and the Order of the Red Banner of Labor (1975). On November 4, 1976, Lyul'ka was awarded the Lenin Prize for the T-6 complex (the Su-24 plane with the AL-21F engine).

After Lyul'ka's death (June 1, 1984), the design bureau he had headed since 1946 was named after him. In addition, there is a square in Moscow, next to the Lytkarino Engineering Works, which bears the name of Academician Lyul'ka. Today, these enterprises—the Lyul'ka Research and Development Center and the Lytkarino Engineering Works—are incorporated in OAO Saturn Research and Production Association, which specializes in the design and large-scale manufacture of gas turbine engines for civil and military aviation, power plants, gas compressor units, and power plants for ship propulsion. Saturn is involved in R&D of the 117C engine for the Su-35 fighter-bomber, whose scheduled flying test took place in 2007; a fifth-generation engine for an advanced warplane meant to become the main strike frontline aircraft of the Russian Air Force for a long time; and the AL-55 engine, which was chosen by the Air Force of the Republic of India for instructional aircraft. The design, technological, and production services of the Lyul'ka Research Center and the Lytkarino Engineering Works are taking part in the design of the SAM146 engine for the SSJ regional passenger aircraft, engines for the Russian Navy, small-size gas-turbine engines for pilotless aircraft, and a wide range of 2.5–110 MW power and gas compressor units for OAO Gazprom and RAO UES of Russia. The legacy of General Designer Academician Lyul'ka persists.

A.A. Sarkisov,

General Designer,

OAO NPO Saturn